

Executive Summary

The California Air Resources Board entered environmental tobacco smoke (ETS) into the process of identifying substances as Toxic Air Contaminants. OEHHA has, in this document, updated the report on health effects of environmental tobacco smoke first released in 1997 (Cal/EPA, 1997) and later published by the U.S. National Cancer Institute (NCI, 1999). This document, in conjunction with the 1997 OEHHA report (Cal/EPA, 1997; NCI, 1999) serves as the health effects assessment pursuant to Health and Safety Code Section 39660 et seq. We summarize the findings of the original report on each endpoint, and add to those findings based on our review of the more recent literature.

The Children's Environmental Health Protection Act of 1999 amended the Toxic Air Contaminants statute by explicitly requiring considerations of any evidence on : 1) differences in exposure patterns between infants and children and adults; 2) special susceptibilities of infants and children to the effects of candidate TACs; 3) interactions between TACs and criteria air pollutants, and 4) interactions of chemicals acting by similar mechanisms. This document examines the evidence for the effects of ETS on infants and children including both prenatal and postnatal exposure. We have provided summaries of major studies on the effects of ETS exposure on children in each chapter for endpoints that were studied in children. We summarize below the evidence of adverse health effects in children resulting from exposure to ETS.

Children are intrinsically exposed to air contaminants at a level exceeding that of adults in the same setting due to higher breathing rates per body weight and lung surface area relative to adults. These elevated breathing rates are related to a higher oxygen demand due to growth and development as well as generally higher physical activity levels. This elevated exposure rate would also apply to ETS. In addition, younger children do not generally have a choice of environment. As such, they cannot remove themselves from exposure like an older child or adult could. As described in Part A, this is reflected in the latest serum cotinine measurements in the Third National Health and Nutrition

Examination Survey, where levels in people exposed to passive smoke were highest in young children (Mannino et al., 2001).

Exposure to environmental tobacco smoke (ETS) has been linked to a variety of adverse health outcomes. Although great strides have been made in the reduction of ETS exposure in the workplace, many Californians are still exposed at home, at work and in public places. In the comprehensive reviews published as *Reports of the Surgeon General* and by the U.S. Environmental Protection Agency (U.S. EPA) and the National Research Council (NRC), and the earlier OEHHA review (Cal/EPA, 1997) ETS exposure has been found to be causally associated with respiratory illnesses, including lung cancer, childhood asthma and lower respiratory tract infections. Scientific knowledge about ETS-related effects has expanded considerably since the release of these reviews. The State of California has therefore undertaken a broad update of the previous ETS document, covering the major health endpoints potentially associated with ETS exposure: perinatal and postnatal manifestations of developmental toxicity, adverse impacts on male and female reproduction, respiratory disease, cancer, and cardiovascular disease. A “weight of evidence” approach has been used to describe the body of evidence to conclude whether or not ETS exposure is causally associated with a particular effect. Because the epidemiological data are extensive, they serve as the primary basis for assessment of ETS-related effects in humans and are supported by toxicological evidence in animals. The report also presents an overview on measurements of ETS exposure, particularly as they relate to characterizations of exposure in epidemiological investigations, and on the prevalence of ETS exposure in California and nationally.

ETS, or “secondhand smoke”, is the complex mixture formed from the escaping smoke of a tobacco product, and smoke exhaled by the smoker. The characteristics of ETS change as it ages and combines with other constituents in the ambient air. Exposure to ETS is also frequently referred to as “passive smoking”, or “involuntary tobacco smoke” exposure. Although all exposures of the fetus are “passive” and “involuntary”, for the purposes of this review *in utero* exposure resulting from maternal smoking during pregnancy is not considered to be ETS exposure.

Part A is an update of the original document's Chapter 2, and describes how ETS exposure is measured. Constituents of tobacco smoke and their metabolites (e.g., nicotine and cotinine) can serve as biomarkers of recent exposure to ETS.

1. General Findings

ETS is an important source of exposure to toxic air contaminants indoors. There is also some exposure outdoors, in the vicinity of smokers. Despite an increasing number of restrictions on smoking and increased awareness of health impacts, exposures in the home, especially of infants and children, continue to be a public health concern. ETS exposure is causally associated with a number of health effects, including effects on infants and children. ETS has a number of serious impacts on children's health including sudden infant death syndrome (SIDS), exacerbation of asthma, increased respiratory tract infections, increased middle ear infections, and causes developmental toxicity resulting in low birth weight, and impaired lung function growth, predisposition to SIDS (to the extent that this is a developmental effect), and other developmental impacts. If the Air Resources Board lists ETS as a Toxic Air Contaminant, it should be added to the list of TACs that may disproportionately impact children pursuant to Health and Safety Code Section 39669.5(c).

Listed in Table ES.1 are the developmental, respiratory, carcinogenic and cardiovascular effects for which there is sufficient evidence of a causal relationship, including fatal outcomes such as sudden infant death syndrome and heart disease mortality, as well as serious chronic diseases such as childhood asthma. There are in addition effects for which evidence is suggestive of a causal association but further research is needed for confirmation. These include spontaneous abortion, cervical cancer, and chronic respiratory symptoms in adults (Table ES.1). Finally, it is not possible to judge on the basis of the current evidence the impact of ETS on a number of endpoints, including congenital malformations, changes in female fertility and fecundability, male reproductive effects, and rare childhood cancers.

Many Californians are exposed to ETS, and the number of people adversely affected may be correspondingly large. Table ES.2 presents morbidity and mortality estimates for

health effects causally associated with ETS exposure. For some cancer, cardiovascular and some respiratory endpoints, when California specific data are unavailable estimates are derived from figures published for the U.S. population, assuming that the number affected in California would be 12% of the total. The estimates for middle ear infection, sudden infant death syndrome and low birthweight were derived using information on prevalence of ETS exposure in California and the U.S.

Relative risk estimates associated with some of these endpoints are small, but because the diseases are common the overall impact can be quite large. A relative risk estimate of 1.2-1.7 for heart disease mortality in nonsmokers is supported by the collective evidence; this corresponds to approximately 1,700-5,500 deaths annually in California. The relative risk estimate of 1.38 associated with low birthweight implies that ETS may impact fetal growth of 1,600 newborns in California. At least 31,000 children in California experience one or more ETS-related asthma episodes (new onset or exacerbation) each year. Large impacts are also associated with relative risks for respiratory effects in children such as middle ear infection ($RR \approx 1.62$) (about 52,000 children annually), and lower respiratory infection in young children ($RR \approx 1.5$ to 2) (18,000 to 36,000 children annually). ETS exposure is implicated in 21 SIDS deaths per year in California ($RR \approx 3.5$). About 400 to 1100 lung cancer deaths in California are ETS-related. For nasal sinus cancers, observed relative risks have ranged from 1.7 to 3.0. This is as high or higher than the relative risks observed for lung cancer. Finally, for breast cancer, a relative risk estimate of 1.26 is derived from our meta-analysis, and when restricted to studies with better exposure assessment, an overall relative risk estimate of 1.90 is obtained. This represents a significant number of cases as this is a relatively common cancer in women.

TABLE ES.1
HEALTH EFFECTS ASSOCIATED WITH EXPOSURE
TO ENVIRONMENTAL TOBACCO SMOKE

Effects Causally Associated with ETS Exposure

Developmental Effects

Fetal Growth: Low birthweight and decrease in birthweight
Sudden Infant Death Syndrome (SIDS)
Pre-term Delivery

Respiratory Effects

Acute lower respiratory tract infections in children
(*e.g.*, bronchitis and pneumonia)
Asthma induction and exacerbation in children and adults
Chronic respiratory symptoms in children
Eye and nasal irritation in adults
Middle ear infections in children

Carcinogenic Effects

Lung Cancer
Nasal Sinus Cancer
Breast Cancer

Cardiovascular Effects

Heart disease mortality
Acute and chronic coronary heart disease morbidity
Altered vascular properties

Effects with Suggestive Evidence of a Causal Association
with ETS Exposure

Reproductive and Developmental Effects

Spontaneous abortion, IUGR
Adverse impact on cognition and behavior
Allergic sensitization
Decreased pulmonary function growth
Adverse effects on fertility or fecundability
Menstrual cycle disorders

Cardiovascular and Hematological Effects

Elevated risk of stroke in adults

Respiratory Effects

Exacerbation of cystic fibrosis

Chronic respiratory symptoms in adults

Carcinogenic Effects

Cervical cancer
Brain cancer and lymphomas in children
Nasopharyngeal cancer

Table ES.2 Attributable Risks Associated with ETS

	Conclusion OEHHA 1997	Conclusion OEHHA 1997	Conclusion Update	Conclusion Update
Outcome	Excess # in CA	Excess # in US	Excess # in CA	Excess # in US
Pregnancy: Low Birth Weight Pre-term Delivery	1,200-2,200	9,700-18,600	1,600 4,700	24,300 ¹ 71,900
Cardiac death (Ischemic heart disease death)	4,200-7,440	35,000-62,000	1,700-5,5000 ²	22,700- ³ 69,600
Lung Cancer Death	360	3,000	400 ⁴	3400
Asthma (children)				
Episodes			31,000 ⁵	202,300 ⁶
New cases	960-3120	8,000-26,000		
Exacerbation	48,000-120,000	400,000- 1,000,000		
Lower respiratory illness	18,000-36,000	150,000- 300,000	N/A	N/A
Otitis media visits	78,600-188,700	700,000- 1,600,000	51,700 ⁷	789,700 ⁸
SIDS	120	1,900-2,700	21 ⁹	431 ¹⁰
Breast cancer			All studies: OR 1.26 (95% CI 1.10-1.45) ¹¹ Best studies: OR 1.90 (95% CI 1.53-2.37) Approximate 26 - 90% increased risk	

¹ Based on adult females reporting exposure to ETS in NHANES III for 1995 (Pirkle et al., 1996)

² Based on California Dept Health Services.

www.dhs.ca.gov/hisp/chs/OHIR/vssdata/2000data/OOCh5pdf/5_9_Reorg.PDF, Table 5-9 for yr 2000

³ Based on Anderson and Arias (2003). National Vital Statistics Report. Vol 51(9) Table 2 for yr 2000 Ischemic heart diseases including AMI.

⁴ Assuming California exposure and death rates are similar to national rates and California population is 12% of national population.

⁵ Based on number asthma attacks or episodes in previous 12 months for 0-17 year olds. Calculated from California Health Interview Survey for 2001

⁶ Based on number asthma attacks or episodes in previous 12 months for 0-14 year olds. CDC-MMWR 2002 51(SS01)

⁷ Calculated by applying national value (H6) and assuming 12% of US population lives in California

⁸ Based on National Center for Health Statistics Series 13 No. 137. Ambulatory Health Care Visits by Children: Principal Diagnosis and Place of Visit for yrs 1993-1995.

⁹ Based on California Dept Health Services. www.dhs.ca.gov/hisp/chs/ohir/vssdata/2000data/OOch4pdf/8reorg.pdf. Table 4-8 for yr 2000

¹⁰ Based on National Center for Health Statistics. www.cdc.gov/nchs/fastats/infort.htm for yr 2000

LBW = low birth weight; N/A = data not available.

¹¹ OEHHA is unable at this time to calculate an attributable risk as it is not possible to account accurately for the portion attributable to other known risk factors. The OR for all studies is based on our meta-analysis of all studies overall risk estimates. The OR for best studies is based on the OR for all studies which did a better job of ascertaining exposure – see Section 7.4.1.3 and Table 7.4.1B).

2. Specific Findings and Conclusions

2.1. Perinatal Manifestations of Developmental Toxicity

ETS causes developmental toxicity. ETS exposure adversely affects fetal growth, with elevated risks of low birth weight or “small for gestational age” observed in numerous epidemiological studies. The primary effect observed, reduction in mean birthweight, is small in magnitude. But if the distribution of birthweight is shifted lower with ETS exposure, as it appears to be with active smoking, infants who are already compromised may be pushed into even higher risk categories. Low birthweight is associated with many well-recognized problems for infants, and is strongly associated with perinatal mortality. ETS is also associated with pre-term delivery. Premature babies are at higher risk for a number of health problems.

The impact of ETS on perinatal manifestations of development other than fetal growth is less clear. The few studies examining the association between ETS and perinatal death are relatively non-informative. Studies on spontaneous abortion are suggestive of a role for ETS, but further work is needed. Although epidemiological studies suggest a moderate association of severe congenital malformations with paternal smoking, the findings are complicated by the use of paternal smoking status as a surrogate for ETS exposure, since a direct effect of active smoking on sperm cannot be ruled out. In general, the defects implicated differed across the studies, with the most consistent association seen for neural tube defects.

2.2. Postnatal Manifestations of Developmental Toxicity

Numerous studies have demonstrated an increased risk of sudden infant death syndrome, or “SIDS,” in infants of mothers who smoke. Until recently it has not been possible to separate the effects of postnatal ETS exposure from those of prenatal exposure to maternal active smoking. Recent epidemiological studies now have demonstrated that postnatal ETS exposure is an independent risk factor for SIDS.

Although definitive conclusions regarding causality cannot yet be made on the basis of available epidemiological studies of cognition and behavior, there is suggestive evidence

that ETS exposure may pose a hazard for neuropsychological development. With respect to physical development, while small but consistent effects of active maternal smoking during pregnancy have been observed on height growth, there is no evidence that postnatal ETS exposure has a significant impact on growth in otherwise healthy children. As discussed in greater detail below, developmental effects of ETS exposure on the respiratory system include adverse effects on lung growth and development and childhood asthma induction.

2.3. Female and Male Reproductive Toxicity

Active smoking by women has been found to be associated with decreased fertility in a number of studies, and tobacco smoke appears to be anti-estrogenic. The epidemiological data on ETS exposure, though not conclusive are suggestive of adverse effects on fecundability and fertility. Newer studies reviewed in the update suggest adverse effects of ETS exposure on menstrual cycle disorders. Regarding other female reproductive effects, while studies indicate a possible association of ETS exposure with early menopause, the analytic methods of these studies could not be thoroughly evaluated, and therefore at present, there is not firm evidence that ETS exposure affects age at menopause. Although associations have been seen epidemiologically between active smoking and sperm parameters, conclusions cannot be made regarding ETS exposure and male reproduction, as there is very limited information available on this topic.

2.4. Respiratory Effects

ETS exposure produces a variety of acute effects involving the upper and lower respiratory tract. In children, ETS exposure can exacerbate asthma, and increases the risk of lower respiratory tract illness, and acute and chronic middle ear infection. Eye and nasal irritation are the most commonly reported symptoms among adult nonsmokers exposed to ETS. Odor annoyance has been demonstrated in several studies.

Regarding chronic health effects, there is compelling evidence that ETS is a risk factor for induction of new cases of asthma (in children and adults) as well as for increasing the severity of disease among children and adults with established asthma. In addition,

chronic respiratory symptoms in children, such as cough, phlegm, and wheezing, are associated with parental smoking. While the results from all studies are not wholly consistent, there is evidence that childhood exposure to ETS affects lung growth and development, as measured by small, but statistically significant decrements in pulmonary function tests; associated reductions may persist into adulthood. The effect of chronic ETS exposure on pulmonary function in otherwise healthy adults is likely to be small, and unlikely by itself to result in clinically significant chronic disease. However, in combination with other insults (*e.g.*, prior smoking history, exposure to occupational irritants or ambient air pollutants), ETS exposure could contribute to chronic respiratory impairment in adults. In addition, regular ETS exposure in adults has been reported to increase the risk of occurrence of a variety of lower respiratory symptoms.

Children are especially sensitive to the respiratory effects of ETS exposure. Children with cystic fibrosis are likely to be more sensitive than healthy individuals. Several studies of patients with cystic fibrosis, a disease characterized by recurrent and chronic pulmonary infections, suggest that ETS can exacerbate the condition. Several studies have shown an increased risk of atopy (a predisposition to develop IgE antibodies against common allergens, which can then be manifested as a variety of allergic conditions) in children of smoking mothers, though the evidence regarding this issue is mixed.

2.5. Carcinogenic Effects

The role of ETS in the etiology of cancers in nonsmokers was explored, as smoking has been recognized as an established cause of a number of cancers (lung, larynx, oral cavity, esophagus and bladder), and a probable cause of several others (cervical, kidney, pancreas, and stomach). Also, ETS contains a number of constituents that have been identified as carcinogens.

Reviews published in the 1986 *Report of the Surgeon General*, by the National Research Council in 1986, and by the U.S. EPA in 1992, as well as the original OEHHA report (CalEPA 1997) concluded that ETS exposure causes lung cancer. Since the previous OEHHA review (Cal/EPA, 1997), numerous epidemiological studies and several meta-analyses have examined the association between passive smoking and lung cancer. The

population-based studies were designed to and have successfully addressed many of the weaknesses for which the previous studies on ETS and lung cancer have been criticized. Results from these studies are compatible with the causal association between ETS exposure and lung cancer already reported by the U.S. EPA, Surgeon General, and National Research Council. The studies examining the effect of ETS exposure on nasal sinus cancers consistently (though not uniformly) show statistically significant associations, presenting strong evidence that ETS exposure increases the risk of nasal sinus cancers in nonsmoking adults. Finally, studies of the association between nasopharyngeal cancer and ETS suggest elevated risks.

Epidemiological studies, supported by animal data, provide evidence consistent with a causal association between ETS exposure and breast cancer in humans, which appears stronger for pre-menopausal breast cancer. Studies assessing the association between passive smoking and breast cancer have generally reported a positive, and often statistically significant association. This risk appears to vary by several factors including menopausal status and timing of exposure, factors not always controlled or analyzed for in studies, including the large U.S. cohort studies. Perhaps for these reasons, in addition to concerns of potential ETS exposure misclassification due to limited or excluded ascertainment of occupational, childhood or total lifetime exposure, most of the large cohort studies available have not identified significantly elevated increases in breast cancer risk. However, the more recent primary, population-based case-control studies (as well as three cohort studies), controlling for several important reproductive, dietary and other potential confounding factors, have consistently identified elevated breast cancer risks for residential and occupational exposure overall or in individual strata. Higher risks were noted for breast cancer diagnosed in women under age fifty (premenopausal) and women exposed peri-pubertally and prior to first pregnancy. The toxicological data on tobacco smoke constituents continues to strongly support that the cancer risk associated with active smoking and with ETS exposure alone remains highly plausible. In comparison to studies reviewed in the previous OEHHA report (Cal/EPA, 1997), current epidemiological and toxicological data are substantially more indicative of a positive association between ETS exposure and breast cancer risk, particularly in

subgroups of women defined by early age of exposure onset, menopausal status, or underlying genetic susceptibility (e.g. for metabolic enzymes). Future studies need to account for these other factors to establish the extent of this exposure-disease relationship. Overall, the weight of evidence (including biomarker, animal and epidemiological studies) is consistent with a causal association between ETS and breast cancer. Our conclusion is primarily based on the strength of the evidence in younger women (< age 50) diagnosed prior to menopause.

The epidemiological and biochemical evidence suggest that exposure to ETS may increase the risk of cervical cancer. Positive associations were observed in three of four case-control studies and a statistically nonsignificant positive association was observed in the only cohort study conducted. A new population-based cross-sectional study found statistically significant elevated risks for cervical cancer. Findings of DNA adducts in the cervical epithelium as well as nicotine and cotinine in the cervical mucus of ETS-exposed nonsmokers provides biological plausibility.

Precursors of endogenously formed N-nitroso compounds suspected of causing brain tumors are present in high concentrations in ETS. In adults, the epidemiological evidence for an association between ETS exposure and risk of brain tumor remains weak and inadequately researched. More recent studies have focused on the potential association between ETS and childhood brain tumors. In children, recent studies or others not previously reviewed by OEHHA, provide no substantial evidence for an association between maternal smoking and childhood brain tumors, with risk estimates generally near the null. Several studies indicated a slightly stronger association with paternal smoking and brain cancer, although the association is still somewhat weak. The most recent and largest individual study (Filippini et al., 2002) did not consistently observe statistically elevated brain cancer risk. However, the pooled estimate of risk from the Oxford Survey of Childhood Cancers studies (together the largest sample size of the studies reviewed), comparing paternal smokers versus paternal nonsmokers, did find a significantly elevated risk of deaths in offspring of smokers from tumors of the central nervous system for all three time periods combined (Sorahan et al., 1997b). Overall, the generally positive, but inconsistent, associations reported between paternal smoking and

childhood brain tumors, in combination with biologically plausible hypothesis, provide suggestive evidence of an association between ETS and brain cancer in children. Similarly, suggestive evidence of an association between exposure to ETS and childhood cancer is noted for lymphomas and acute lymphocytic leukemia (children of paternal smokers).

For other cancer sites in adults, there has been limited ETS-related epidemiological research in general: there is currently insufficient evidence to draw any conclusion regarding the relationship between ETS exposure and the risk of occurrence of cancer in sites other than lung, nasal cavity, breast, and possibly brain and lymphoma and leukemia. A review of the available literature clearly indicates the need for more research. For example, although compounds established as important in the etiology of stomach cancer are present in tobacco smoke, only a single well designed population based study has been performed for this site. In biochemical studies of nonsmokers, higher levels of hemoglobin adducts of the established bladder carcinogen, 4-aminobiphenyl, have been found in those exposed to ETS. However, no significant increases in bladder cancer were seen in the two case-control studies and one cohort study conducted to date, although both studies were limited in their ability to detect an effect.

The epidemiological data on ETS exposure and rare childhood cancers provide an inadequate foundation for making conclusions regarding causality. Some studies found small increased risks in children in relation to parental smoking for neuroblastoma, Wilm's tumor, bone and soft-tissue sarcomas, but not for germ cell tumors. Studies to date on these rare cancers have been limited in their power to detect effects. The impact of ETS exposure on childhood cancer would benefit from far greater attention than it has received to date.

2.6. Cardiovascular Effects

The epidemiological data, from prospective and case-control studies conducted in diverse populations, in males and females and in western and eastern countries, support a conclusion that there is a causal association between ETS exposure from spousal

smoking and coronary heart disease (CHD) mortality in nonsmokers. To the extent possible, estimates of risk were determined with adjustment for demographic factors, and often for other factors related to heart disease, such as blood pressure, serum cholesterol level and obesity index. Risks associated with ETS exposure were almost always strengthened by adjustment for other confounders. For nonsmokers exposed to spousal ETS compared to nonsmokers not exposed, the risk of CHD mortality is increased by a factor of about 1.3. The association between CHD and risk is stronger for mortality than for non-fatal outcomes, including angina. It is also evident that these effects exacerbate or are exacerbated by underlying conditions, and individuals with other chronic conditions such as diabetes, vascular disease or hypertension comprise a susceptible population at even greater risk from ETS exposure.

Data from clinical and animal studies suggest various mechanisms by which ETS causes heart disease. In a number of studies in which nonsmokers were exposed to ETS, carotid wall thickening, lesion formation, aortic distensibility and reactivity, and compromise of endothelial function were similar to, but less extensive than those experienced by active smokers. Other effects observed include impaired exercise performance, altered lipoprotein profiles, enhanced platelet aggregation, and increased endothelial cell counts. These findings may account for both the short- and long-term effects of ETS exposure on the heart. The data reviewed also suggests that the effects of ETS may also contribute to stroke, the etiology of which includes atherosclerosis of the carotid and large arteries of the brain, and degeneration of intracerebral arteries.

3. References

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